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SCIENTIFIC DEVELOPMENTS IN PASTURE
AND FORAGE PRODUCTION

By Glenn W. BURTON,
Principal Geneticist,
U.S. Department of Agriculture
and University of Georgia,
Tifton, Georgia

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SCIENTIFIC DEVELOPMENTS IN PASTURE AND FORAGE PRODUCTION

Glenn W. Burton, Principal Geneticist
U. S. Dept. of Agriculture and University of Georgia, Tifton, Georgia

1. Permanent pasture occupies 1/5 of the total land area of the world. Although some land now in pasture is suitable for the growth of other crops, most of it is too dry, too steep, too rocky, or too wet at times to successfully grow anything but grass or trees. Thus, on most of the vast grasslands of the world, pastoral farming is the best and usually the only type of agriculture capable of supporting man.
2. Despite its great importance grass is man's most neglected crop. In vast areas, over-grazing has resulted in tremendous loss of grass, soil, water, and animal product. Even in such a scientifically advanced country as Britain, William Davies estimates pasture production could be increased 3- to 12-fold by nation-wide adoption of scientific developments now available (11). In some less developed areas even greater improvements are possible.
3. Sir George Stapledon in his presidential address presented to the Fourth International Grassland Congress in 1937 said, "the basic principles of growing grass are the same the world over" (20). If this be true, the less developed areas of the world should find the world's grassland research and experience most useful as they improve their own grassland farming. As they, with the aid of others, endeavor to do this, they must remember that grassland agriculture is a complex system that involves the interaction of the soil, the plant, and the animal that consumes it. A shift in any one of these components inevitably affects the balance and the performance of the whole system. The skill of the man who controls the system is often as important as any of its components. The great skills required to realize the maximum grassland potential in any area help to explain why few have achieved this objective.
4. It is the purpose of this paper to describe a few of the scientific developments in pasture and forage production that have generally improved grassland outputs. The degree to which they may be effective in other lands will be determined by the skill of those who endeavor to introduce them into the existing grassland agriculture.

STOCKING GRASSLANDS PROPERLY

5. In his plenary address to the Eighth International Grassland Congress, William Davies declared, "It can be calculated that of the dry matter grown on British grasslands in a normal year, no more than one-half passes through the grazing animal. The remainder is wasted, so far as the animal is concerned -- obviously a most serious matter. Part of the wastage occurs on the pastures themselves during the process of grazing, and part of it during conservation as hay or silage" (11). This statement would apply equally well to the grasslands in most of the humid temperate regions of the world.
6. At the same Congress, R. O. Whyte, speaking of the arid and semi-arid

grasslands between the Atlantic and Rajasthan said, "We find degraded natural grazing lands of many ecological types reduced below their optimal conditions in botanical composition and carrying capacity by the uncontrolled grazing of excessive numbers of livestock for too long a period each year" (22). Overgrazing hurts the animal, the grass, the soil, the owner of the animal, those whose livelihood lies within the watershed of the grassland, the nation involved, and ultimately the world.

7. Overgrazing so far as the animal is concerned occurs when the yield of animal product from a pasture over a period of years is below the optimum. Obviously overgrazing so defined may be so close to undergrazing as to be impossible to detect and avoid. Overgrazing so far as the plant is concerned occurs when the better forage plants lose vigor and are gradually replaced with less desirable species. When this occurs, the yield of animal product will also decline.

8. The adverse effects of overgrazing obviously increase with its intensity. Animals are so constituted that maintenance requirements must be met before there can be reproduction or growth. Over 70% of the digestible nutrients consumed by a 500-pound steer gaining one pound per day is required for maintenance. When grazing becomes so short that he can consume only the four pounds of TDN per day required for maintenance, he produces nothing for his owner. The food consumed keeps the animal alive for man's use or consumption another day, but does nothing more. This relationship is so important as to warrant a simple example shown in Table 1. This is based on the work of Sylvestre and Williams that shows that a 500-pound steer requires 4.09 pounds of TDN for maintenance and an additional 1.71 pounds of TDN per pound of daily gain (21). It assumes the TDN production per acre would remain constant with increased grazing intensity. Repeated research proves that TDN production would no doubt decrease with increased intensity of overgrazing. It assumes further that two pounds is the maximum average daily gain physiologically possible by steers kept on this range regardless of the amount of forage available.

Table 1. The effect of stocking rate on the production of 100 acres of range land for 100 days.

Number of steers on the range	Type of Grazing	Percent of TDN used for gains	Total pounds of liveweight gain or loss on the range
7	Light undergrazing	31.8	1400 gain
10	Optimum grazing	45.5	2000 gain
13	Light overgrazing	29.6	1300 gain
17	Medium overgrazing	7.4	325 gain
20	Heavy overgrazing	0.0	390 loss

9. As grazing pressure exceeds the optimum, the pasture produces less and less food for man (Table 1). Carried to the extreme, human food is actually lost as animal body weight and later animal numbers decrease. As grazing pressure increases, the reserve forage to carry animals through severe droughts and floods disappears.

10. In the Masai district of Kenya in 1960, there were 500,000 head of cattle, three times as many as the range should have carried. At the end of a severe drought in that year, half of the cattle were dead and many more died later during floods. The Masai tribe most affected by this catastrophe suffered greatly and were forced to turn to growing crops in an effort to survive (12). Table 1

shows that had they had fewer cattle they could have produced more food and would have had reserve forage to keep their cattle alive during adverse weather conditions.

11. In addition to causing these direct losses of animal product, overgrazing weakens and destroys the best forage plants, and thus further reduces the quantities of food available to grazing animals. The reduction in ground cover that follows permits more rainfall loss due to runoff and reduces forage yields accordingly. The irreparable loss of soil and plant nutrients associated with the greater runoff further reduces the growth of plants that are left. The increased runoff of soil and water steps up the many losses due to flooding and the entire watershed is affected adversely. The resultant losses to the nation and the world are apparent.
12. In order to realize the potential of any grassland, animal numbers must be adjusted to utilize as much forage as possible without permitting long-time adverse effects on forage plants and grazing animals. Since grasslands rarely produce forage at a constant rate, man must resort to many ingenious devices to obtain the maximum production from them. He must first learn by experience or research the grazing pressure that each type of grassland will tolerate. Some types may do better with complete utilization followed by complete rest. Other types perform as well or better under continuous grazing.
13. Moving animals to areas with more abundant herbage is the answer of the nomad who must utilize free range areas. This method is as old as civilization and is effective in the hands of experts where there is enough forage to meet animal needs. Where animal numbers exceed the supply of forage, all of the problems associated with overgrazing result.
14. Generally the output of grasslands can be increased materially by stocking for optimum production during the growing season. This is true because storage of grass in situ to feed animals in the off-season usually results in considerable loss of TDN. In the more successful grassland countries, animals are bred so their offspring can make maximum use of forage during the growing season. At the end of the season, these young animals and culls are moved to slaughter or to areas of food surplus for finishing. The breeding herd may then be kept on a submaintenance diet that will result in some loss in body weight until the growing season brings fresh forage again. Where this technique has been exploited most effectively it has been shown that mature cows in good condition can lose 50 to 125 pounds in the off-season without affecting their health or reproductive rates, provided the quantity and quality of the forage during the growing season will permit them to feed their young and regain their normal weight.
15. Grasslands that have deteriorated because of overgrazing can usually be improved by shortening the grazing season or by reducing the number of animals. This allows the desirable species that have been weakened by overgrazing to increase in size and vigor. This method can only hope to succeed where living plants and seeds of the desirable species still remain. The effectiveness of this method in improving grasslands has been demonstrated many times. Hedy reported "phenomenal results in range improvement have resulted from control of livestock numbers in scattered locations in Kenya, Tanganyika and Southern Rhodesia" (13).
16. At the Eighth International Grassland Congress, Mohammed Said reported that after four years of protection from grazing, annuals had increased and perennials were beginning to appear in the Quetta-Kalat Region of West Pakistan where "the grasses and bushes are eaten down to the very root-stock and are not given any chance to make new growth." In this large region

occupying 43% of the land area of West Pakistan, "Sheep are not sold under 2 years of age because, on account of insufficient feed, they do not attain the desired size for marketing before that age." Sheep grazing for nine months on this range after four years of protection "increased in weight considerably and were generally in good health." Lambs from ewes on this range reached a marketable weight of 70 pounds at seven months of age. The improved range, stocked at the rate of 170 acres per sheep per year, was divided into six pastures that were grazed rotationally (17).

CONTROLLING BUSH AND WEEDS

17. In natural grasslands where grass is the climax vegetation, the presence of bush and weeds is often a good index of overgrazing. Here, reducing the grazing pressure will often reduce the annual weeds materially. Where the undesirable plants are perennials, such as sagebrush, *Artemisia* sp., and they are in dense stand their elimination can result in rapid recovery of associated grazing plants. In California spraying *Artemisia tridentata* (growing with a fair stand of suppressed grasses) with 2,4-D resulted in a fourfold increase in forage production by the second year (9).

18. Mowing *Artemisia filifolia* in June for two consecutive years and excluding livestock to permit the native grasses to develop decreased the brush 98 percent, increased the grass 4 times, and more than doubled the beef production in western Oklahoma (19). Ploughing, disking, railing, beating, and grubbing are other mechanical methods that have frequently been used for bush control. Selecting the right season of the year to apply control measures is most important and varies with the method chosen (11).

19. Fire has long been a useful tool in retarding the development of bush in grasslands. The American Indians were using fire for this purpose when the white man discovered the North American Continent. In the humid southeastern United States where trees make up the climax vegetation, early graziers soon discovered that annual or biennial fires would prevent reforestation and keep the bush under control. Efforts to reforest this area were not successful until methods for fire control were developed. Heady observed "that the areas burned most frequently and severely in the semi-arid region of East Africa also had less grazing pressure and were in better condition than those areas where grazing was heavy and fire less frequent" (13). It is Heady's opinion that: "Principles in the use of fire as a range-management tool are yet to be discovered. Semi-arid East Africa offers an excellent place to find them" (13).

20. In the humid and semi-arid areas of the world, mowing has been an effective method of controlling some pasture weeds. Deferring grazing and cutting hay occasionally from grasslands have helped to control weeds at little if any cost.

21. Chemical herbicides are becoming increasingly important as tools for controlling bush and weeds in pastures. Many broadleaved weeds growing in grass pastures can be controlled more effectively and at lower cost with one or more applications of 2,4-D than with other control measures. Herbicides that can selectively remove most of the broadleaved weeds from many of the forage legumes are now available. Generally weeds are easiest to kill with growth regulator herbicides, such as 2,4-D, when in the young, active growing stage. Hardwood species are usually most susceptible to these herbicides for a short period following full leaf expansion.

22. A combination of several methods may increase the control of bush and weeds and reduce the cost as well. Spraying March-burned gallberry, *Ilex glabra*, with

2,4,5 T in water in Aug. gave a better kill than spraying unburned gallberry with 2,4,5-T in either water or oil in May, August, or November. This treatment reduced competition enough to permit a threefold increase in the yield of grass in three years.(6)

23. Bush and weed control can be recommended only if there are available or will be planted desirable species to replace those destroyed. Control measures should destroy all undesirable plants and inflict a minimum of injury on the desirable ones. There is no gain in trading one problem species for another. Only with good grazing management can full and sustained benefit from bush and weed control be realized.

INTRODUCING BETTER SPECIES

24. Some ecologists have contended that the species that occupy an area when the ecological climax has been reached are better adapted than any other species in the world. They would say, "Why try to introduce species from other parts of the world? You have the best now." Although such statements may apply to the natural grasslands of the western United States, they do not apply throughout the world. Even in the western United States, tall bunch grasses, such as needle grass, *Stipa comata*, that constitute the climax under little or no grazing may not make the best livestock feed and may disappear under moderate to heavy defoliation (18). In this connection, it is well to remember that the ecological climax under any environment will be composed of those available species that are best adapted and most competitive. Any change in the environment such as increasing the grazing pressure or applying water or fertilizer can move other species to the top of the list. It is a bit presumptive to assume that, in spite of the natural barriers of oceans and mountains and natural environmental changes, nature has always placed in each spot those species best adapted there.

25. In the humid areas of the world where the climax vegetation is trees, the native grasses and forbs that occur in the open places and understory are frequently inferior forage plants. In the southeastern United States (50 inches of rain per year), the native grasses and forbs that livestock will graze are low in productivity, palatability, and nutritive value. Steers grazing them will produce about eight pounds of liveweight gain per acre per year if the range is not burned. Production can be increased 50% by burning the range. Twenty to 30 acres are required to carry one animal. When these lands are cleared and planted in introduced grasses, such as bahiagrass (*Paspalum notatum*), common bermudagrass (*Cynodon dactylon*), and pangolagrass (*Digitaria decumbens*), their productivity is increased materially. The magnitude of the increase is dependent upon the fertility of the soil and the amount of fertilizer applied. With little or no fertilizer, they will often produce up to 100 pounds of liveweight gain per acre, 12 times the production of the unburned native range. When fertilized with 50 to 100 pounds of nitrogen per acre per year plus phosphorus and potassium as needed, these grasses will produce over 25 times as much as the native grasses they replaced. The native grasses and forbs respond little if any to fertilizer applications.

26. Improving arid and semi-arid rangelands by reseeding has generally been less successful than planting new forages in humid sections. Covas observed that weeping lovegrass (*Eragrostis curvula*) planted in the semi-arid pampean region of Argentina produced 22 times as many steer-days of grazing and over 6 times as much gain per hectare as the natural grassland. Daily gains of steers on the weeping lovegrass, however, were only 0.215 kg. compared with 0.729 kg. for those on the natural pasture. He concluded, therefore, that weeping lovegrass would not be a suitable grass for fattening cattle (10).

27. Many reseeding attempts in the arid range of the western United States have failed because of drought. When successful, the production of the reseeded range has usually been little better than good native range. Consequently, reseeding has usually been limited to overgrazed areas where little grass exists. Native grasses are generally used and when reseeding succeeds it merely returns the range to the more productive status that it once possessed.

28. Where legumes can be successfully introduced into pure grass pastures, production may be increased several fold. Frequently one or more of the following are required: Phosphorus, potassium, lime, minor elements, and water. Good management is essential for the maintenance of such grass-legume mixtures.

BREEDING SUPERIOR VARIETIES

29. Forage grasses and legumes exhibit the same variability and respond to breeding and selection in much the same way as corn, wheat, rice, and other crop plants. Although forages are one of the last groups of economic plants to be subjected to genetic improvement by breeding, superior varieties of a number of species have been developed. The longevity of alfalfa stands has been greatly increased by breeding bacterial-wilt-resistant varieties such as Ranger. Introducing resistance to foliage diseases not only increases yields but also improves the quality of the herbage, since diseased leaves are lower in nutritive value (3). Many improved varieties have been bred to reach their peak of production earlier or later than the ones generally used in order to extend the grazing season. The erect, short ley varieties of ryegrass (*Lolium perenne*) and orchardgrass (*Dactylis glomerata*) sacrifice longevity, not needed in the short ley, for increased production. By lowering the prussic acid content in *Piper sudangrass*, plant breeders greatly reduce the hazards of poisoning associated with grazing this species.

30. Heterosis which occurs in many forages increases the productivity and efficiency of the species whenever it can be used in commercial varieties. Coastal bermudagrass is an example of an F₁ hybrid that produces twice as much forage as common bermuda in wet years and up to six times as much in dry seasons (8). Although it must be propagated vegetatively, it now occupies over three million acres in the United States. The hybrid Gahi-1 pearl millet, *Pennisetum typhoides* will produce 50% more forage and give better seasonal distribution than the common millet it replaces (5).

31. These are but a few examples of the changes plant breeders will be able to make in pasture and forage plants that will result in more efficient livestock production.

FERTILIZING EFFICIENT FORAGE PLANTS PROPERLY

32. Except for the arid sections, where lack of water limits growth, applying fertilizer will usually increase forage yields. The amount of the increase is influenced by many factors, not the least of which is the efficiency of the crop. In a year when rainfall was adequate, common bermudagrass, Coastal bermudagrass, and carpetgrass growing side by side and fertilized with 200 pounds of nitrogen, phosphate, and potash per acre produced 3.2, 6.2, and 2.0 tons of dry matter per acre. Thus, Coastal bermudagrass was twice as efficient as common bermudagrass and three times as efficient as carpetgrass in fertilizer use.

33. Well inoculated legumes obtain their nitrogen from the air by symbiosis and need only the other nutrients required for plant growth. Of these phosphorus, potassium, and calcium are the ones that most frequently must be added due to

soil deficiencies. Legumes usually require several times more potassium than phosphorus. In addition to these elements, grasses must have nitrogen, and growth is often related directly to the amount of nitrogen applied. In 1953, a year of good rainfall with adequate amounts of other nutrients, Coastal bermudagrass fertilized with 0, 100, 300, 600 and 900 pounds of nitrogen per acre produced 1.9, 5.7, 9.7, 12.6 and 13.4 tons of hay per acre respectively (15).

34. It is wasteful to apply more of one element than is needed, particularly if it is apt to be lost by leaching or soil fixation. Research has shown that Coastal bermudagrass will make excellent growth over a period of years on infertile sandy soils when fertilized with a 4-1-2 ratio of N, P_2O_5 , and K_2O . To apply a 1-1-1 ratio of these elements would obviously waste P_2O_5 and K_2O . Soil tests furnish a good guide for determining fertilizer practices once the nutrient needs of a forage have been established.

35. When the most efficient grasses are properly fertilized, great increases in livestock production may be obtained in humid regions. Coastal bermudagrass fertilized with 200 pounds of nitrogen and 500 pounds of 0-10-20 annually carried an average of $3\frac{1}{2}$ steers and produced 684 pounds of liveweight gain per acre per grazing season for three years (4). This is 57 times the 12-pound liveweight gain obtained from an acre of burned native range in this area.

IRRIGATING WHERE POSSIBLE

36. The importance of water in improving pasture and forage production is well understood. In arid regions irrigation can increase forage yields many times. Here the few acres that can be irrigated are usually used to produce hay and supplemental feeds for those seasons when range grazing is short. These limited acreages could be made to produce much more than they usually do if all of the best forage production practices were combined.

37. Forage plants differ greatly in their water-use efficiency. Coastal bermudagrass, for example, requires only about half as much water as common bermudagrass to produce a pound of forage (8). When adequate water is supplied by rainfall or irrigation, Coastal bermudagrass fertilized with 400 pounds of nitrogen and other nutrients as needed will produce 5 to 10 times as much forage as when not fertilized at all. But, Coastal bermudagrass fertilized with 400 pounds of nitrogen per acre will produce from 10 to 20 times as much forage per acre as the unfertilized common type. Thus by combining an improved variety with heavy fertilization the increase is much greater than from either practice alone. Since potential evapotranspiration rates tend to be constant regardless of plant variety, the 20-fold increase in yield just described can be had without adding any more water. In arid regions where water is always inadequate, opportunities to increase irrigated land production by combining all of the best production practices should not be overlooked.

SUPPLEMENTING PASTURE IN OFFSEASON

38. In the temperate zone, cold weather terminates grass growth during the winter months. In much of this area the winter gap in feed production is usually bridged with hay or silage harvested from the range in the peak season or produced on other acres. In arid sections, where there is likely to be little rain or snow, livestock are given small quantities of high protein pellets to supplement the frosted grass. This method is successful only where there is an adequate supply of frosted grass available. Even in these instances forage quality is sacrificed as the grass matures and weathers. In humid regions weathering

losses are much greater, limiting the usefulness of frosted grass to a period of four to six weeks past the first killing frost in the fall.

39. In the tropics a dry season often limits forage production as cold does farther north. Here the same methods outlined above may be used to supply feed during these periods. If supplements can be produced on other acres and can be preserved in the form of hay or silage, the range can be stocked at a heavier rate during the growing season.

40. In regions where severe droughts are common, the range is usually stocked at much less than the optimum rate in order to insure an adequate supply of feed should a drought develop. If supplemental feed can be produced in more favorable sites, perhaps under irrigation, and stored in the form of hay or silage, the grazer can utilize the range more completely, knowing that feed reserves are available should a severe drought develop. Silage would be preferable to hay for this purpose since silage keeps much better than hay during prolonged storage.

UTILIZING FORAGE AT A STAGE THAT GIVES MAXIMUM YIELDS OF DIGESTIBLE NUTRIENTS

41. Generally forages decrease in digestibility and palatability with increase in age. In Oklahoma, prairie hay cut in June was higher in protein, phosphorus, and digestible nutrient content than that cut in July, August, or September. Cutting in July, however, gave the greatest yield of hay and total digestible nutrients per acre (2).

42. Baker et al. obtained similar results in Nebraska when they compared prairie hay cut in early July, early August, and mid-September. Growing calves fed each hay with and without supplement gained best and required the least feed per unit of gain when fed the young hay. Intake decreased and percent hay refused increased as the hays advanced in maturity (1).

43. In New York State, protein content, digestibility, intake, and milk production were increased as the first cutting date was advanced (set at an earlier date). Yield losses resulting from cutting the various forages early were largely offset by increased yields of aftergrowth (16).

44. At Tifton, Georgia, 3-year average dry-matter yields of 6.8, 7.2, 7.9, 8.9, 9.0, and 6.5 tons per acre were obtained from Coastal bermudagrass plots cut every 3, 4, 5, 6, 8, 12 and 24 weeks, respectively, for a 24-week period each year. Crude protein dropped from 18.5 to 8.4%, vitamin A equivalent dropped from 199,900 to 32,800 I.U. and crude fiber increased from 27.0 to 33.9% as the age of the grass when cut increased. The Coastal bermudagrass in this study was fertilized annually with 600 pounds of nitrogen and 1500 pounds of 0-10-20 per acre. Although in vitro digestibilities decreased with increasing age of the grass when cut, the maximum yield of digestible dry matter was obtained when the grass was cut every 6 weeks (7). Heifers fed only 4-, 8-, and 13-week-old Coastal bermudagrass hay gained 1.18, .75, and 0.00 pounds per day.

45. The data summarized above indicate that young forage will give the best animal response. In order to get the maximum yield of digestible nutrients, however, some quality must be sacrificed. Forage plants that are good under proper management become unpalatable and of little value when allowed to grow old and stemmy. Management programs designed to utilize pastures and forages most efficiently must embody these truths.

CONCLUSIONS

46. The application of presently available scientific developments in pasture and forage production could increase the output of the world's grasslands many fold. The program for maximum grassland production must include a combination of all desirable practices that will apply in any area. The best pasture and forage plants for the area, properly fertilized and managed, must be so fed to improve livestock that they in turn will produce the maximum yield of animal product per acre. Grassland production programs highly successful in one area may be poorly suited to another. Consequently, specific programs must be developed for each area that differs greatly in soil, climate, and natural vegetation. Although these programs may be found eventually through trial and error, they can be most efficiently developed by "on site" applied research.

47. C. P. McMeekan addressing the recent World Food Forum emphasized that much of the amazing grassland development of New Zealand was the result of good, applied research carried out in each area. Many of the basic principles of good grassland management have been well established. Applied research workers, equipped with this knowledge, must work out the best pasture and forage program for each area. They must compare in well designed experiments those management systems that would seem to be most likely to succeed. Their studies must involve the soil, the plant, and ultimately the animal that consumes it. It is not enough, for example, to evaluate new promising pasture and forage varieties in only one unaltered environment. These plants must be tested on different sites, alone and in association with other species, and with varying levels of plant nutrients and water. Their forage-production potential and seasonal distribution of growth must be determined. Their drought and cold tolerance must be cataloged. Their resistance to insects, nematodes, and plant diseases must be noted. Their efficiency in fertilizer and water use should be ascertained. New species not previously tested must be checked for the presence of poisonous compounds. Ease of establishment and control must be considered. Actual grazing or clipping to simulate grazing must be introduced early in the testing program in order to ascertain the response of new pasture plants to such treatments. Always answers to the question "Why?" should be sought.

48. The main question should always be not, "What will the grazier do?" but "What could be done?" Twenty-five years ago many believed that southern United States farmers would never fertilize pastures. Some said it was a waste of time to conduct fertilizer experiments on pasture crops. Today many southern farmers fertilize pastures because applied research proved that it was profitable to do so. A leading pasture specialist 20 years ago said, "Farmers will not plant a pasture grass that will not produce seed." Today over 3 million acres of Coastal bermudagrass, all planted vegetatively, prove that farmers will plant a vegetatively propagated grass in their pastures when applied research proves that it pays.

49. Applied grassland research of the best kind cannot increase the output of world grasslands without effective education. The pasture and forage production programs must be made so attractive and so easily understood that every farmer for whom they are designed will use them. This calls for the development of new teaching methods, better than the best available today.

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